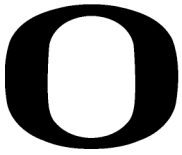

UNIVERSITY OF OREGON

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# Reducing IT Costs and Increasing IT Efficiency by Integrating Platform-Virtualization in the Enterprise

CAPSTONE REPORT

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## Abstract

Selected literature, published between 1999 and 2009, is examined in relation to reducing IT cost and increasing IT efficiency through implementation of platform-virtualization within the enterprise. Virtualization can reduce IT cost through server consolidation, test and development agility, licensing consolidation, standardization, and/or power and physical space consolidation. It can also increase IT efficiency through centralized administration and/or security, support of legacy systems, reduction of server downtime, and/or providing the staff training on a new technology.

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# Introduction

## *Problem*

Each year, organizations worldwide spend billions of dollars on their information technology (IT) infrastructure (Ramanathan & Bruening, 2004). Business's today are under ever increasing pressure to reduce operational costs while still ensuring that flexibility, service delivery levels, and business efficiency continue to improve. Organizations are investing considerable time, effort, and hard cash to achieve this (Conoops, 2007). Data center environments are becoming more complex and heterogeneous, with correspondingly higher management costs (VMware, 2006). As part of an effort to rein in operations cost increases, Golden and Scheffy (2007) suggest that a platform-virtualization model offers the opportunity to reduce overall system administration costs in comparison to non-virtual environment, by reducing the overall number of machines that need to be utilized.

This study examines platform-virtualization, which encompasses the virtualization of the physical hardware and the operating systems that reside on that hardware. Ramanathan and Bruening (2004) state, "Platform virtualization can be defined as the creation of a logically partitioned computing system that runs on top of an actual platform. While virtualization has been applied to storage and servers, the concept of platform-virtualization goes further to include all layers of the platform – from applications and operating software to platform components, processors and interconnects. Virtual platforms are perceived by users – and function in all respects – as if they were physical computers" (p. 1).

Yang (2008) defines platform-virtualization as a technique used to replicate the functionality of real hardware platform so that one physical machine can host more than one

system level software without conflict. Hamm (2005) states, "virtualization has the potential to dramatically change the way corporate computing is done. With servers, it lets one physical machine behave like a half-dozen virtual machines, and it also makes it possible to move an application from one machine to another on the fly" (p. 2). The Strategic Counsel (2007) states "server virtualization is becoming a mainstream technology, having been adopted by at least 39% of worldwide organizations with more than 500 employees" (p. 4).

### *Significance*

According to The Strategic Counsel (2007), there is a strong link between server virtualization and top business drivers for IT. As identified by The Strategic Counsel survey respondents, top business drivers for IT are: reducing IT costs, increasing IT efficiency; improving organizational or business performance; and improving IT service levels. The Strategic Counsel also finds that "the benefits of server virtualization are clear and extremely well aligned with organizational expectations and actual server virtualization use cases. Primary benefits include improved server / system utilization rates; improved server reliability and uptime; and improved business continuity and disaster recovery" (p. 21).

The term "business driver" refers to factors in the industry or the broader business environment that either impact the financial institution or provide opportunity for business expansion (Bruel & Price, 2007). Business functions are related to ("business drivers", 2008) and refer to a series of logically related activities or tasks (such as planning, production, sales) performed together to produce a defined set of results. The Great Britain Office of Government Commerce (2002) states "business drivers are the attributes of a business functions that drive the behavior and implementation of that business function in order to achieve the strategic business objectives of the company. In other words, business drivers are the primary reasons the business

wants to employ the business function…" (Information Technology Infrastructure Library (ITIL), p. 15).

Virtualization technologies allow IT organizations to consolidate multiple workloads onto a single server, resulting in more efficient use of each server, and fewer of them to install, support, and manage (Sun, 2008). Kennedy (2007) states, "In some client situations, a more comprehensive virtualization solution is required, such as hosting a legacy application on a new operating system. In that case, it may be best to isolate an application within a complete, virtualized OS environment — the classic "virtual machine" approach. This enables you to run an application within the OS image of your choice while still supporting migration to, and integration with, newer or otherwise incompatible OS platforms" (p. 31). It is a way of maximizing physical resources to maximize the investment in hardware (Ou, 2006). Mann (2007) states "Virtualization has many significant advantages, both for IT and for the business as a whole. These success factors are contributing to specific competitive advantage, cost reduction, and productivity benefits for many organizations" (p. 2).

Platform virtualization has proven to reduce the total cost of ownership (TCO) in the organization. Van Doorn (2006) demonstrates three examples of this reduction:

1. Increases system utilization (current servers have less than 10% utilization).
2. Reduces hardware (25% of the TCO).
3. Conserves space, electricity, and cooling (50% of the operating costs of a data center).

Business continuity and disaster recovery preparedness are also important benefits of a virtual

environment. Schwab (2006) states "virtualization and streaming allow for easier software migration, including system backup and recovery, which can make it extremely valuable as a disaster recovery or a business continuity planning solution. Virtualization can duplicate critical servers, so that it does not need to maintain expensive physical duplicates of every piece of hardware for disaster recovery purposes. Disaster recovery systems can even run on dissimilar hardware" (p. 8).

### *Purpose*

The purpose of this literature review is to examine the potential advantages and disadvantages of migrating from a non-virtual environment to a hardware-virtualization model in support of information system administration in the enterprise, with emphasis on two IT business functions provided by The Strategic Counsel (2007): reducing IT costs and increasing IT efficiency. **(**Two other business functions noted by The Strategic Counsel but not examined in this study include improving organizational or business performance and improving IT service levels**)**. As an example, Samoilenko (2007) provides a preliminary list of some of the key factors associated with such a migration:

1. Compatibility and support (which could be related to the business function of "increasing IT efficiency").

2. Licensing (which could be related to the business function of "reducing IT costs").

3. Planning deployment (which could be related to the business function of "increasing IT efficiency").

4. Return on Investment (ROI) (which could be related to the business function of "reducing IT costs").

5. Staff/Support Training (which could be related to either business functions: reducing IT costs and increasing IT efficiency).

The goal during data analysis is to identify the factors for consideration when migrating from an existing environment to a virtual one in relation to IT cost and efficiency. The reported advantages and disadvantages of each factor when migrating to a hardware-virtualization model are examined in relation to these two selected IT business functions.

***Audience / Outcome***

This document is intended for IT professionals, specifically system administrators; however it should be reviewed by stakeholders involved, with or interested in, installing and/or migrating systems to a virtual environment. For this review, a system administrator is defined as a person who manages the computer systems in an organization, who can create and manage accounts and groups, understands how operating systems perform, access control, understands how to set account policies and user rights, is familiar with how to set up auditing and read audit logs, and can configure other similar system-related functionality (Kirch, 2007). The intent is to provide these IT professionals with enough knowledge to discuss the business justification to move to a hardware-virtualization environment or to maintain the platform-specific model with company stakeholders.

The outcome of this review is presented in the form of an annotated framework that describes factors for consideration in relation to two pre-selected key IT business functions,

when migrating the environment from a platform-specific to a virtual one proposed by The Strategic Counsel (2007): reducing IT costs, and increasing IT efficiency. The annotated framework is presented in two main categories. The first is the background of virtualization for the purpose of establishing context. Second are factors, along with advantages and disadvantages, for consideration when migrating from an existing environment to a virtual one, framed from the perspective of the two pre-selected IT business functions. For example, a factor for consideration within the IT business function of "reducing IT cost" is hardware consolidation. An advantage of hardware consolidation is described by Mann (2007) who states "Server consolidation and improved server utilization is another major benefit from virtualization, and is one of the traditional drivers as well. Enterprises can combine the workload from multiple underutilized physical machines into a single physical system. This dramatically reduces overall hardware spending, as it requires far fewer physical systems for the same application workload" (p. 3).

### *Research Limitations*

*Time frame.* Collection of materials for this literature review is focused on those published from 1999 to 2009. In some cases, articles prior to 1999 are used when they pertain to discussions of the foundation of the virtual platform technology. The 1999 date was selected because it is based on a significant milestone in the overall development of virtualization. Virtualization has long been used in the mainframe and large system world as a safe and reliable method of improving IT efficiency (Gabriel Consulting Group, 2007). However, on February 8, 1999, VMware introduced the first x86 virtualization product, ("VMware Virtual Platform", n.d) based on earlier research by its founders at Stanford University.

*Selection criteria.* The primary sources for the literature are retrieved from ACM Portal, Clusty, EBSCO Host, Google, Google Scholar, IEEE Digital Library, Summit, and WorldCat. Preference is based on relevance to the topic, depth of analysis, and date published (Leedy & Ormrod, 2005). As a member of IEEE, this researcher has access to articles not available to the general public. Limited availability materials are noted in the references list and are available from www.ieee.org.

*Audience.* This document is intended for IT professionals, specifically system administrators, but should be reviewed by stakeholders involved with or interested in installing and/or migrating systems to a virtual environment. The intent is to provide these IT professionals with enough knowledge to discuss with stakeholders, the business justification to move to a hardware-virtualization environment or to maintain the non-virtual environment within the company.

*Topic definition.* Platform-virtualization refers to partitioning the physical machines' memory into separate and isolated "virtual machines", designed to simulate multiple machines within one physical machine. Partitioning enables multiple copies of the same or different operating systems to run on the hardware, and also prevents applications from interfering with each other (Computer Desktop Encyclopedia, 2008). A virtual infrastructure has become a powerful enabler for consolidating servers, for running applications in multiple operating system environments, for simplifying administration and for lowering operating costs (Intel, 2005).

*Topic focus.* In this study, the emphasis is focused on how platform virtualization has the potential to impact two closely related business functions; reducing IT costs and increasing IT efficiency. These two IT business functions were preselected from a set of four that included

reducing IT costs; increasing IT efficiency; improving organizational or business performance; and improving IT service levels (The Strategic Counsel, 2007). These two IT business functions were selected for this study because they have the most impact on the day-to-day operations of a company.

Reduction of IT costs was selected because of its importance to the reduction of the total cost of ownership (TCO). TCO is defined as including the cost of the hardware, software and upgrades as well as the cost of the in-house staff and/or consultants that provide training and technical support (Computer Desktop Encyclopedia, 2008). Increasing IT efficiency was selected because of its importance to the demands for operational support overall across the company. Many IT departments are faced with the need to provide more capabilities under shrinking budgets. Small and medium-size businesses (SMB) are trying to balance increasing IT budget demands with constricting IT budget funds (Eddy, 2008). Increasing IT efficiency can be linked to the concept of return on investment or ROI. To improve return on investment ROI and reduce TCO, organizations need to make the most of what is already in place.

*What will not be included.* This review does not focus on benchmark reviews of hardware, installation or configuration of different hardware or software solutions, review all the possible platforms or operating systems that can support a virtual environment, or recommend/promote a specific vendor's solution.

### *Data Analysis Plan Preview*

The larger approach to data analysis selected for this study is the data analysis spiral (Leedy & Ormrod, 2005, p. 151, figure 1). This spiral has four steps to follow: first the selected reference materials are organized, then they are perused for a gain of overall sense, next they are

classified into groups based on predetermined criteria, and lastly they are synthesized to create the final report. A more specific approach is added as a guide during the synthesis step. Using a content analysis process from Busch et al. (2005) known as conceptual analysis, the data to be collected from the selected references is coded as factors for consideration when migrating from an existing environment to a virtual one, including the potential advantages and disadvantages of each factor. Factors collected for this report are coded in relation to categories corresponding to the two pre-selected IT business functions which form the focus of this study: reducing IT costs and increasing IT efficiency (The Strategic Counsel, 2007).

### *Writing Plan Preview*

A literature review helps provide meaningful context to a research project within already existing research (Obenzinger, 2005). Data collected during the conceptual analysis process from existing research are presented in an annotated framework format. The framework begins with headings followed by information about the two areas: background of virtualization, followed by factors for consideration when migrating to a virtualization model in the enterprise, in relation to two pre-selected IT business functions: reducing IT costs and increasing IT efficiency and the advantages and disadvantages of these two factors.

The factors are structured according to a "thematic" organizational pattern, examining virtualization as a current option for organizations rather than focusing on the history of the technology. Thematic reviews of literature are organized around a topic or issue, rather than the progression of time (Literature review, 2007). In this case the themes are defined by the two pre-selected IT business functions. An outline of the anticipated organization of information is presented below:

1) A brief and selected history and background of virtualization, as a way to establish context.

2) A description of two pre-selected key IT business functions and related lists of factors for consideration, pertaining to the migration process. Including a review of the reported advantages and disadvantages of each factor when migrating the current environment to a virtual one.

## Definitions

The definitions section presents terms used in the literature review. Definitions are designed to describe concepts, environments, terms and things that relate to virtualization and virtualization environments, as these concepts are utilized in this study. Terms are mined from literature reviews, initial concept terms, and key word searches.

**Business drivers:** The factors in the industry or the broader business environment that either impact the financial institution or provide opportunity for business expansion (Bruel & Price, 2007).

**Business functions (Business Process):** Series of logically related activities or tasks (such as planning, production, sales) performed together to produce a defined set of results (BusinessDictionary, n.d.).

**Data center:** Computer facility designed for continuous use by several users, and well equipped with hardware, software, peripherals, power conditioning and backup, communication equipment, security systems, etc. (BusinessDictionary, n.d.).

**Emulation:** The binary translation of one instruction set into another, whether from x86 instructions to PowerPC instructions, or from x86 instructions to virtualized x86 instructions (Microsoft, 2003).

**Enterprise**: A business organization (def. #2) (Collins Essential English Dictionary 2nd Edition, 2006).

**Hardware virtualization**: Partitioning the computer's memory into separate and isolated "virtual machines" simulates multiple machines within one physical computer. It enables multiple copies of the same or different operating systems to run in the computer and also prevents applications from interfering with each other (Computer Language Company, n.d.).

**Host operating system:** A virtual machine monitor or host called a hypervisor to enable multiple operating system instances to run on a single physical server (Goth, 2007).

**Guest operating system:** The guest operating system running on a layer above the hypervisor. It can also run within an operating system, with the guest OS running on the third layer above the hardware (Goth, 2007).

**Hypervisor:** A thin layer of software that generally provides virtual partitioning capabilities that runs directly on hardware, but underneath higher-level virtualization services (VMware, 2006).

**Information Technologies (IT) Infrastructure**: Set of tools, processes, and methodologies (such as coding/programming, data communications, data conversion, storage and retrieval, systems analysis and design, systems control) and associated equipment employed to collect, process, and present information (BusinesDirectory, n.d.).

**Legacy application:** An older application that is often no longer supported (Microsoft, 2003).

**Legacy operating system:** An older operating system, often incompatible with up-to-date hardware. Virtual machines allow you to run legacy operating systems on new hardware (Microsoft, 2003).

**Legacy Systems**: Existing computer system that provides a strategic function for a specific part of a business (BNET, n.d.).

**Migration:** A change from one hardware or software technology to another. Moving data from one storage system to another (data migration). Moving data and applications from one computer to another (TechWeb, 2008).

**Non-virtual environment**: All of the resources on the physical computer are permanently dedicated to the applications running on that computer (Kirch, 2006).

**Paravirtualization**: The name for another approach to server virtualization. In this approach, rather than emulate a complete hardware environment, the virtualization software is a thin layer that multiplexes access by guest operating systems to the underlying physical machine resources (Golden & Scheffy, 2007).

**P2V**: Term for physical-to-virtual when discussing environment migration (Vanover, 2007).

**Partitioning**: The ability to run multiple operating systems on a single physical system and share the underlying hardware resources (VMware, 2006).

**Platform Virtualization:** A technique used to replicate the functionality of real hardware platform so that one physical machine can host more than one system level software without conflict (Yang, 2007).

**Return on Investment (ROI)**: The monetary benefits derived from having spent money on developing or revising a system (Computer Language Company, n.d.).

**Sandbox:** A restricted environment in which certain functions are prohibited (Computer

Language Company, n.d.).

**Server Virtualization**: Server virtualization is where the base hardware of a system is virtualized, allowing multiple guest operating environments to run directly on top of the hardware, without requiring a complete host Operating System (Schwab, 2006).

**SMB**: Small to Medium-sized Business also called "SME" (small to medium-sized enterprise) typically refers to companies with 25 to 500 employees; however, some SMB/SME ranges use an upper limit of 5,000 employees (Computer Language Company, n.d.).

**Streaming**: A subset of other virtualization technologies, which provides a way for software components, including applications, desktops, and complete Operating Systems, to be dynamically delivered from a central location to the end-user over the network (Schwab, 2006).

**Total Cost of Ownership (TCO)**: Includes the cost of the hardware, software and upgrades as well as the cost of the in-house staff and/or consultants that provide training and technical support (Computer Language Company, n.d.).

**Virtual Machine Monitor (VMM):** Software that runs in a layer between a hypervisor or host operating system and one or more virtual machines that provides the virtual machine abstraction to the guest operating systems. With full virtualization, the virtual machine monitor exports a virtual machine abstraction identical to a physical machine, so that standard operating systems (e.g., Windows 2000, Windows Server 2003, Linux, etc.) can run just as they would on physical hardware (VMware, 2008).

**X86 virtualization:** Refers to the Intel x86 family of CPU chips, which includes the Core, Pentium and preceding models such as the 486 and 386. x86-based computers, including

machines with x86-compatible CPUs from AMD and others, make up the world's largest hardware platform (EconomicExpert, n.d.).

## Research Parameters

Information in the research parameters section of the document provides an overview of the methods used to develop the literature review. There are eight sub-sections including:

1. Research questions and sub-questions.
2. Key Search Terms.
3. Search Strategy.
4. Documentation Approach.
5. Evaluation Criteria.
6. Preliminary Search Results.
7. Detailed Data Analysis Plan.
8. Detailed Writing Plan.

The sub-sections detail how the research is conducted and evaluated, and provide an explanation as to how the mined data will be presented.

### *Research Questions and Sub-Questions*

A set of main and sub-research questions guide the search strategy for this report. The main question "What is the potential impact of integrating a hardware-virtualization model over an existing single-server model in the enterprise?" Relevant sub-questions that spawned from the main question are:

- What is the history of virtualization in the enterprise?
- What key IT business functions are likely to be most involved in a virtualization migration?
- What potential benefits exist when implementing a virtual environment?
- What potential drawbacks exist when implementing a virtual environment?

***Key search terms***

"To increase the chances of retrieving relevant information from a search you need to create a description of the subject of interest. This takes the form of a set of words or phrases, which are known as 'search terms' or 'keywords'"(Hewett, 2002, p. 16).

Initial search terms were known by this researcher from previous experience and through reading technology trade publications. New terms and keywords emerged from the initial search and helped focus and further develop the final search terms used for the inquiry.

The set of search terms used:

- "Virtualization"
- "Virtualization total cost of ownership/ Virtualization TCO"
- "Virtualization Performance"
- "Platform Virtualization"
- "Virtualization benefits"
- "Virtualization return on investment/ Virtualization ROI"
- "Virtualization drawbacks"

- "Virtualization Development"
- "Virtualization Security"
- "Hypervisor"

### *Search Strategy*

Keywords and search terms were used for inquiries in this literature review. The tools, terms, and sources used are outlined below.

*Search Engines.* The primary search engines used for this literature review are Clusty, Google, Google Scholar, Summit, and WorldCat. These search engines have had the most consistent and relevant results.

*Databases.* ACM Digital Library, EBSCO Host, IEEE Digital Library, are the databases have had the most relevant results during the data gathering phase. As a member of IEEE, this researcher has access to articles not available to the general public. Limited availability materials are noted in the references list and are available from www.ieee.org.

*Search Terms.* References to support the literature review are collected by using the search terms and the controlled vocabularies listed below. This researcher knew many terms initially, however, some new terms are incorporated into the search as more knowledge of the topic is gained.

### ***Key search terms.***

- "Virtualization"
- "Virtual Machine, VM and/or VMM"

- "Platform Virtualization"
- "Enterprise Virtualization"

***Sub-topic Search Terms.***

- "Pros and Cons"
- "Advantages and drawbacks"
- "Return on Investment (ROI)"
- "Total Cost of Ownership"
- "VM/VMM Host"
- "x86 Virtualization"

***Server and software virtualization.***

- "Application Virtualization"
- "Software Virtualization"

***Virtualization technologies existing today.***

- "Virtualization Technology (VT)"
- "Virtual Machine Monitor"

***Security concerns with virtualization.***

- "Threat"
- "Risk"

- "Virtual Machine Discovery"

***Technical Specifications.***

- "Open Virtual Machine Format"
- "Hypervisor"

***Documentation Approach***

Literature is mined using the World Wide Web as the sole source for scholarly texts and documents (Leedy & Ormrod, 2005). Once literature is retrieved, it is cataloged electronically into folders that directly correspond to the three main categories: a) history of virtualization, b) factors for consideration to reduce IT costs when migrating from an existing environment to a virtual one, and c) factors for consideration to increase IT efficiency when migrating from an existing environment to a virtual one. Both factors also include the potential advantages and disadvantages of each factor during the migration to the new model. Results are stored in a final set of electronic folders with sub-folders that correspond to the sections of the literature review. These sub-folders are labeled with the specific area of interest: history; factors – cost – advantages; factors – cost – disadvantages; factors – efficiency – advantages; factors – efficiency – disadvantages; and so on, as well as a category labeled factors – other (relating to articles that have useful information but are not able to be put into a specific category).

***Evaluation Criteria***

Literature is initially evaluated based on relevance to the topic and selected time frame 1999 to 2009. In some cases, articles prior to 1999 are used when they pertain to discussions of the foundation of the virtual platform technology. Article preference is based on relevance to the

topic, depth of analysis, and date published. Article quality and credibility is determined based on three criteria: 1) Search location – if the literature is published in a scholarly journal, industry trade journal or referenced in a determined scholarly search engine or database, it is deemed credible; 2) If the literature is written for a more advanced audience, for example, IT professionals rather than general audience overviews, it is deemed as a quality piece of literature; and 3) If the article is not a focused advertisement for a specific product, then it is deemed as potentially credible article. All other articles that did not fit these criteria are discarded.

Critical evaluation of selected information sources and credibility of the literature is based on the following five criteria (Smith, 2008):

1) Authority – What are the author's credentials, reputation among peers, what is the association with a reputable institution or organization?

2) Objectivity – Is there bias, does the author state the goals of the publication, and does the information appear valid and well researched?

3) Quality – Is it well organized, are there spelling, grammar or typographical errors?

4) Coverage – Is other material used and referenced, what facts, statistics, evidence is used and are there gaps?

5) Currency – How recently is the research completed?

Evaluations of these criteria are related to the audience needs as well as the goals of the study.

## Preliminary Search Results

The primary search engines and databases for this report are ACM Digital Library, Clusty, EBSCO Host, Google Scholar, IEEE Digital Library, Summit, and WorldCat are the most useful search engines for this research inquiry.

The most productive database for this report is the IEEE Digital Library. As a member of IEEE, this researcher has access to articles not available to the general public. Limited availability materials are noted in the references list and are available from www.ieee.org. EBSCO Host, Summit, and ACM Portal also have accurate results, however, in some cases, acquiring the resource was more difficult to receive. Based on the most relevant hits from a search engine, WorldCat was the most beneficial search engine. Google Scholar and Clusty also had positive results, however in many cases; the number of articles that had to be mined for relevant information was prohibitive. Table1 illustrates the search engines used and the results.

| Search Engine / Database | Search Terms | Results | Quality of Results |
|---|---|---|---|
| **UO Libraries Catalog (EBSCO Host) Academic Search Premier** | "Virtual Machine" | 1,079 | Fair to Low - Too many articles |
| | "Enterprise Virtualization" | 5 | Fair - Some good articles |
| | "Hardware Virtualization" | 21 | Fair - Some good articles |

| Search Engine / Database | Search Terms | Results | Quality of Results |
|---|---|---|---|
| | "Platform Virtualization" | 2 | N/A |
| | "Server Virtualization" | 144 | Good - many articles to choose from. |
| **Summit** | "Virtual Machine" | 147 | Poor - Few related articles |
| | "Enterprise Virtualization" | 12 | Good - Relevant articles to choose from. |
| | "Hardware Virtualization" | 2 | N/A |
| | "Platform Virtualization" | 0 | N/A |
| | "Server Virtualization" | 26 | Fair - Some good articles |
| **ACM Portal** | "Virtual Machine" | 16,314 | Good - Relevant articles to choose from. |

| Search Engine / Database | Search Terms | Results | Quality of Results |
|---|---|---|---|
| | "Enterprise Virtualization" | 332 | Fair - Some good articles |
| | "Hardware Virtualization" | 862 | Good - Relevant articles to choose from. |
| | "Platform Virtualization" | 731 | Fair - Some good articles |
| | "Server Virtualization" | 969 | Good - Relevant articles to choose from. |
| **Google Scholar** | "Virtual Machine" | 95,500 | Poor - Too many articles |
| | "Enterprise Virtualization" | 61 | Fair - Some good articles |
| | "Hardware Virtualization" | 501 | Fair - Some good articles |
| | "Platform Virtualization" | 78 | Poor - Few related articles |

| Search Engine / Database | Search Terms | Results | Quality of Results |
|---|---|---|---|
| | “Server Virtualization” | 486 | Good - many articles to choose from. |
| **IEEE Digital Library** | "Virtual Machine" | 100 | Fair to Low - Too many articles |
| | “Enterprise Virtualization” | 3 | Poor - No related articles |
| | “Hardware Virtualization” | 100 | Fair to Low - Too many articles |
| | “Platform Virtualization” | 29 | Poor - Not a lot of related articles |
| | “Server Virtualization” | 77 | Poor - Not a lot of related articles |
| **WorldCat** | “Virtual Machine” | 2,947 | Fair to Low - Too many articles |
| | “Enterprise Virtualization” | 41 | Good - many articles to choose from. |

| Search Engine / Database | Search Terms | Results | Quality of Results |
|---|---|---|---|
| | "Hardware Virtualization" | 56 | Good - many articles to choose from. |
| | "Platform Virtualization" | 20 | Poor - No related articles |
| | "Server Virtualization" | 131 | Good - many articles to choose from. |
| **Clusty** | "Virtual Machine" | 3,032,000 | Fair to Low - Too many articles |
| | "Enterprise Virtualization" | 3,531,000 | Fair to Low - Too many articles |
| | "Hardware Virtualization" | 2,969,000 | Fair to Low - Too many articles |
| | "Platform Virtualization" | 1,356,000 | Fair to Low - Too many articles |

| Search Engine / Database | Search Terms | Results | Quality of Results |
|---|---|---|---|
| | "Server Virtualization" | 3,602,000 | Fair to Low - Too many articles |

Table 1: Preliminary search results

***Data Analysis Plan***

The references collected for this report are initially qualitatively analyzed by using the data analysis spiral (Leedy & Ormrod, 2005, p. 151). This spiral has four steps to follow: first the selected reference materials are organized, then they are perused for a gain of overall sense, next they are classified into groups based on predetermined criteria, and lastly they are synthesized to create the final report.

The data analysis process used in this study to support the synthesis step is called 'conceptual analyses'. In conceptual analysis, a concept is chosen for examination, and the analysis involves quantifying and tallying its presence (Busch et al., 2005). The focus of the process is on two main aspects of virtualization integration, which form the key concepts used for coding: reducing IT costs and increasing IT efficiency. Sub concepts that are coded for are related to the advantages and disadvantages in relation to the two pre-selected IT business functions, such as return on investment and total cost of ownership. Server virtualization has identifiable benefits that are aligned with organizational expectations, business drivers for IT, and actual server virtualization use cases (The Strategic Counsel, 2007). Drawbacks can include cost accounting (hardware, license compliance); human issues (training); vendor support (lack of

license flexibility); system management complexity; and security (possible new threats) (Mann, 2007).

These aspects of virtualization integration form the key concepts used to design the specific conceptual analysis process. Coding proceeds through a series of eight selective reduction steps (Busch et al., 2005). These steps include:

1. Level of analysis. The level of analysis for the coding process is based on sets of words and phrases. These words and phrases have been identified as:
    - Reducing IT costs.
    - Increasing IT efficiency.
2. Number of concepts to code for. The initial different concepts or phrases that will be coded for are:
    - “Cost”
    - “History”
    - “Efficiency”
    - “Virtualization”
    - “Return on Investment” / “ROI”
    - “Total Cost of Ownership” / “TCO”
    - “Pros and Cons”

3. Code for existence or frequency of a concept. The data is coded for existence as well as frequency of concepts and terms. The number of times the term is used can indicate the relevance as well as importance of the term within the document. It is understood that the number of times a term is used may not always indicate the relevance in the literature. Because of this, translation rules are setup to help offer a level of consistency and coherence. These rules are defined in step 5: Rules for coding text. If a term or concept is found within the literature, it is flagged. The more flagged terms or concepts, the stronger the probability the literature is valid for review. All term and concept hits will be reviewed to ensure that the literature is relevant to the topic or sub-topics. The decision to code for both existence and frequency is possible because of software that will be used to assist in coding process. The software that will be used, *Word Count Machine 2.5.1 (http://wordcounter.profusehost.net/),* has the ability to find the term as well as count the number if times the term is used.

4. How to distinguish among concepts. A narrow level of generalization is applied when mining the data. Search terms and coding for existence should focus enough on the concepts that a wide level of generalization is not necessary.

5. Rules for coding texts. Translation rules offer a level of consistency and coherence. Taking the terms and phrases from step 1: level of analysis; articles are coded for the existence of the term or phrase. A translation rule

stipulates that only references to the listed terms or phrases will be coded. This will ensure consistency in the coding process.

6. Decide what to do with irrelevant information. Information deemed irrelevant will be reexamined as a possible direction to relevant data once the initial coding is completed.

7. Code the text. Two methods of coding are used for this literature review. Coding by hand, a manual process of reading the article and writing the concept occurrences, is more time consuming, but more effective to really mine the material collected. The second method is automated with the use of a word context analyzer: *Word Count Machine 2.5.1.* Using this tool will speed the process of mining the data for key words and phrases; however, it will take an added step to copy the data from downloaded PDF format and paste it into the analyzers.

8. Analyzation of results. Concepts are reviewed throughout the mined text and aligned with one of the major coding concepts, identified in process step 2: The number of concepts to code for. Concepts that can be aligned in one of these major areas: virtualization history, reducing IT cost, or increasing IT efficiency is maintained as part of the data analysis findings. Concepts that cannot be aligned are rejected as irrelevant data.

### *Writing Plan*

The Writing Plan guides the development of the Review of Literature section of the document and follows the "thematic" organizational pattern, examining virtualization as a current option for organizations rather than focusing on the history of the technology. Thematic reviews of literature are organized around a topic or issue, rather than the progression of time (Literature review, 2007). However, progression of time may still be an important factor in a thematic review.

Obenzinger (2005) identifies seven key rhetorical patterns that literature reviews typically follow. This review follows the "Road Map" rhetorical pattern which is defined as: "the researcher traces the history of knowledge in this field, one achievement after another, one study building on the work of the previous one, all of which points to one destination which happens to be the current work" (Obenzinger, 2005, p. 4). The rhetorical pattern supports the goal of this literature review by compiling and synthesizing relevant data collected, and the outcome will provide IT professionals with enough knowledge to discuss the business justification to move to a hardware-virtualization environment or to maintain the platform-specific model with company stakeholders.

Data mined from articles that have been deemed relevant to this review focus on two main aspects of virtualization integration: reducing IT costs and increasing IT efficiency. Information selected during data analysis and deemed relevant to the topic is combined into a detailed framework with three main headings. Sub-topics identified during the coding process are included. The anticipated outline, based on preliminary data review, follows:

1. **Background of virtualization.**

    A. Timeline of virtualization.

    B. Early Mainframe virtualization.

    C. Modern x86 platform virtualization.

2. **Factors for Consideration.**

    A. *Reducing IT Costs.*

        - Server consolidation.
        - Test and Development Agility
        - Licensing Consolidation.
        - Power utilization.
        - Physical space consolidation.

    B. *Increasing IT Efficiency.*

        - Centralized Security.
        - Centralized Administration (reporting, server management, log reviews, etc.)
        - Legacy Systems Support.
        - Reduction of Downtime.

- Staff Education.

## 3. Conclusion

## Annotated Bibliography

The references included in the Annotated Bibliography are selected as the foundation for the "Review of the Literature" section. Each of the twenty-two selections includes an abstract that summarizes the content of the selection for the reader. The researcher's comments are also included for clarification as to how the reference is used in support of this study. Evaluation of author's credibility was done by following guidelines presented by Smith (2008). Smith (2008) states, "In evaluating the credibility of an information source there are several key areas to consider:

- The Authority of the author and the publisher: Are they well qualified to speak to the topic at hand?
- The Objectivity of the author.
- The Quality of the work.
- Coverage of the work.
- Currency: When was the research completed and how recently the work published?"

As a member of IEEE, this researcher has access to articles not available to the general public. Limited availability materials are noted in the References list and are available from www.ieee.org.

Chao, W. (2006). *The Pros and Cons of Virtual Machines in the Datacenter*. Retrieved November 23, 2008 from DevX Web site: http://www.devx.com/vmspecialreport/Article/30383

**Abstract**: This article discusses the pros and cons of today's virtual machine technology to help you determine whether the cost of implementing virtual machine technology is worthwhile. Should the VM benefits outweigh the drawbacks in your multi-server datacenter, virtual machine technology can provide more reliability, easier manageability, and lower overall cost for your organization.

**Comment**: Features and benefits sections explain the key benefits of virtual machine technology: isolation, standardization, consolidation, ease of testing, and mobility. Discusses some of the drawbacks and challenges of virtual machine technology: concentration risk, cost, performance penalty, hardware support, and software licensing. The challenge of deploying virtual machine technology is figuring out whether the benefits outweigh the costs in your situation. This article is used to support the advantages and disadvantages sub-section of the document. This article is credible because the author has been active in the business of technology for many years, has been involved with software and hardware since the mid 1980s. He has been writing Web-based software in a variety of languages and on different platforms since 1994. The article is published in an online technology journal that specializes in IT software and hardware development.

Conoops, A. (2007). Virtualization: Big Picture. *Business Trends Quarterly*. Retrieved January 4, 2009 from: http://btquarterly.com/?mc=virtualization-big-picture&page=virt-viewresearch

**Abstract**: This article discusses the some of the challenges that businesses are facing and how virtualization can assist in today's business environments. It discusses the importance of understanding your business requirements from an IT standpoint, and

discusses some ways how virtualization should be used, some of the options that virtualization offers to the business, and what some of the future offerings will be in virtualization.

**Comment**: This article is used to support the business aspects of the review including the "Test and Development Agility", "Server Consolidation", "Business Continuity", and general advantages and disadvantages of this study. This article is used to support the advantages and disadvantages sub-section of the document. This article is credible because the author is the Operations Director of the Virtualization Academy. He has 25 years of IT experience, primarily within operations. He has worked both in the financial management and the intellectual property management industries. During this time he has delivered and managed many different operational solutions on a range of platforms including IBM AS/400, Novel, and Windows. In 1996, he joined Computer Patent Annuities, one of the world's largest intellectual property management organizations, and became Senior Manager Global Technology in 1999 with responsibility for developing, delivering, and managing a strategic global IT infrastructure.

Duntemann, J. (2005). Inside the Virtual Machine. *PC Magazine*, 24(16), 66-101. Retrieved November 24, 2008, from http://www.pcmag.com/article2/0,2817,1854434,00.asp

**Abstract**: This article focuses on virtual PCs. Virtualization of operating systems is one of those things that is hard to understand until one has actually seen it work. Special software creates a CPU mechanism called a virtual machine (VM), in which Windows can run under Windows, in a window, as can Linux, OS/2 Warp, Solaris, or almost any other operating system written for x86 hardware. The virtualization software is called a

virtual machine manager (VMM) or hypervisor. The virtual machine created by the VMM is an emulation of a completely independent PC. Virtualization's implications for software developers, beta testers, and support professionals are immense. No more one-OS-per-PC and no more waiting for an OS to boot up before use. An OS running in a VM is available instantly. A VM and its OS held in suspension as a disk file can be restored in seconds, with running applications and utilities, right where they were when the VM was suspended. Virtual PC for Mac had long allowed Windows and Windows apps to run on PowerPC-based Macs.

**Comment**: This article provides a good overview of how the virtual environment operates, including an introduction to the hypervisor and other technical details. This article is used to support the background of virtualization as well as historical section of the document, as well as provides information on the different mechanisms that make up a VM. This article has credibility because it is published in a popular technology trade publisher (Ziff-Davis), the author is an accomplished technology writer and editor. He is the Editor-in-Chief of Visual Developer magazine, former editor of Turbo Technix and PC Techniques, the "Structured Programming" columnist for Dr. Dobb's Journal, and has written and edited more than twenty programming books.

Figueiredo, R., Dinda, P., & Fortes, J. (2005). Resource Virtualization Renaissance. *Computer*, 38(5), 28-31. Retrieved November 14, 2008, from the Institute of Electrical and Electronics Engineers, Inc. http://www.computer.org/portal/site/computer/menuitem.5d61c1d591162e4b0ef1bd108bcd45f3/

index.jsp?&pName=computer_level1_article&TheCat=1005&path=computer/homepage/0505&file=gei.xml&xsl=article.xsl&

**Abstract**: Virtualization technologies encompass a variety of mechanisms and techniques used to address computer system problems such as security, performance, and reliability by decoupling the architecture and user perceived behavior of hardware and software resources from their physical implementation. This article focuses on virtual machine monitors (VMMs), a key component of virtual machines that provides a layer between software environments and physical hardware that is programmable. A discussion is presented on the various perspectives of VMMs.

**Comment**: This article concerns the history of virtual technology as well as details of how the virtual machine monitor operates. This article is used to support the history and background of the virtual machine section of the document. This article appears to be credible because it is published by a peer-reviewed publication (IEEE Computer Society). The authors are credible based on their qualifications published in the article:

Renato Figueiredo is an assistant professor in the Department of Electrical and Computer Engineering at the University of Florida. His research interests are in distributed computing, operating systems, and computer architecture. Figueiredo received a PhD in computer engineering from Purdue University.

Peter A. Dinda is an assistant professor at Northwestern University, where he holds the Lisa Wissner-Slivka and Benjamin Slivka Junior Chair in Computer Science. His research interests are in parallel and distributed systems, performance analysis, and adaptive systems. He received a PhD in computer science from Carnegie Mellon University.

José Fortes is a professor and a BellSouth Eminent Scholar at the University of Florida, where he is also the director of the Advanced Computing and Information Systems Laboratory. His research interests are in the areas of distributed computing and information processing, computer architecture, and nano-computing. Fortes received a PhD in electrical engineering from the University of Southern California.

Golden, B., & Scheffy, C. (2007). *Virtualization for Dummies*. Hoboken, N.J. Wiley.

**Abstract**: A guide to virtualization covers such topics as server virtualization, managing a virtualization project, software options, using VMware Server, and implementing XenExpress.

**Comment**: A version of the popular "Virtualization for Dummies" book. It includes some biases because of the sponsors it was modified for – Sun and AMD; however, it is still a very good resource on all aspects of virtualization (history, advantages and disadvantages.) This book is deemed credible because it is published by a well-known publisher (Wiley Publishing), and there is sufficient coverage of the concept, the material is current – published in 2008, and the writing is technical in nature.

The Strategic Counsel (2007). *Global Server Virtualization Survey -Summary Report.* Retrieved November 23, 2008 from http://www.ca.com/files/SupportingPieces/consolidatedreport52607v1.pdf

**Abstract**: Organizations are looking at deploying virtualization for multiple reasons. Whether you are curious, still in the planning stages or already engaged in deployment,

this independent global study, of 800 surveyed organizations, highlights the mixed results companies are experiencing with server virtualization—as well as critical success factors discovered by early adopters. Learn how organizations are deploying virtualization and the benefits and challenges they experienced.

**Comment**: This article contains ROI information as well as best practices information. This article is used to support the advantages and disadvantages (in relation to the IT business function of cost) section of the document. This document is a commissioned survey for CA (formerly Computer Associates International, Inc.), of 969 private and public organizations with a minimum of 500 employees. The survey intent was to determine the deployment incidence, trends and timetables associated with server virtualization; organizations' motivations for moving to virtualized server environments; organizations' IT management issues and constraints with heterogeneous virtualized server environments; and organizations' return from server virtualization deployment. The survey asked IT executives and managers who are specifically final and key decision-makers and influencers for server virtualization to detail their organizations' server virtualization deployments or plans in the following areas:

- Current and future adoption and timelines;
- Implementation status and areas;
- Technology and business drivers for virtualized server environments;
- Key issues in managing virtualized environments;
- Key virtualization benefits, barriers and best practices; and,
- Return on investment and cost savings.

It is a technical article written for IT professionals (CA is an IT management software provider).

Hamm, S. (2005). A Virtual Revolution. *Business Week*, 3938, pp. 98-102. Retrieved November 15, 2008 from: http://www.businessweek.com/magazine/content/05_25/b3938622.htm

**Abstract:** Focuses on new software that makes computing cheaper and more efficient, and accelerates the power shift from sellers to buyers. Discussion of the benefits of virtualization, a major trend in computing; How virtualization software allows one computer server to act like several, so one server can run more than one program; Implications for corporate customers; Advantages for people who buy and manage computers; Views of analysts.

**Comment:** This article is used to support the history and the advantages and disadvantages sections of the document. This is a credible article because it is published in reputable periodical – BusinessWeek, a part of the McGraw-Hill companies. The author is a senior writer for BusinessWeek and focuses on globalization, innovation and leadership.

Kennedy, R. (2007). *Applicatio*n and Desktop Virtualization. *InfoWorld,* 29(7), 28-32. Retrieved November 8, 2008 from InfoWorld Web site: http://www.infoworld.com/article/07/02/12/07FEvirtualapp_1.html

**Abstract**: The article discusses application and desktop virtualization. An example that virtualization is not just for the data center is application virtualization wherein products that insulate running programs from the underlying desktop. Eliminating the support

draining configuration problems that plague conventional desktop implementations is the idea behind application virtualization. One approach to application virtualization is to use products such as Altiris software virtualization solution (SVS) which employs a brute force method that installs a filter driver in the Windows file system code stack to intercept and redirect I/O calls from SVS-managed applications. Another is hosting a legacy application on a new operating system.

**Comment:** This article is used to support the history and advantages and disadvantages of this study. This article is credible because it is published in InfoWorld - a leading publisher of technology information. The author is a contributing editor of the InfoWorld Test Center. The article meets the date range requirements so it is relevant to the review, and it is a high quality article – technically written for an IT professional or systems engineer level.

Kirch, J. (2007). *Virtual Machine Security Guidelines.* The Center for Internet Security. Retrieved November 30, 2008 from http://www.cisecurity.org/tools2/vm/CIS_VM_Benchmark_v1.0.pdf

**Abstract:** This white paper addresses security concerns that apply generally to Virtual Machine technologies. The recommendations contained within are vendor neutral and should apply to most virtualization deployments. Recommendations are based on a variety of public sources and input from members of the Center for Internet Security (CIS).

**Comments:** This whitepaper is used to support the advantages and disadvantages (security) section of the document. This whitepaper is credible for many reasons. The

quality of work is for an IT security expert that is interested in securing a virtual environment. The paper was written for The Center of Internet Security (CIS) provides benchmarks, scoring tools, software, data, information, suggestions, ideas, and other services and materials from the CIS website or elsewhere as a public service to Internet users worldwide.

Kline, T., & Whyms, R., (2007) *Investigating the Use of Virtual Servers to Improve the Restoration Process of an Active Directory Forest.* University of Maryland, Baltimore Center for Information Technology Services. Retrieved November 29, 2008 from http://net.educause.edu/ir/library/pdf/MAC07088.pdf

**Abstract**: This power point presentation is primarily covers a disaster recovery solution for an Active Directory environment that is based on virtual machines. Section two of the presentation provides an overview of virtualization technology and how it can be implemented in the environment.

**Comment**: Using virtualization as a disaster recovery option. Good graphic to reference on the layers of a virtual setup. The presentation provides some historical information as well as advantages and disadvantages of virtualization, including information on disaster recovery. The authors appear to be authorities in the field of virtualization. The presentation is written for the Center for Information Technology Services at the University of Maryland, Baltimore. Presentation quality, coverage, and currency make this a credible article.

Mann, A. (2007). The Pros and Cons of Virtualization. *Business Trends Quarterly*. Retrieved November 27, 2008 from http://www.btquarterly.com/?mc=pros-cons-virtualization&page=virt-viewresearch

**Abstract**: The article provides a breakdown of advantages and disadvantages of implementing a virtualization into the enterprise. The article also discusses the most common virtualization technologies.

**Comment**: A detailed overview of the advantages and disadvantages of virtualization. This article is credible because the author is a Senior Analyst, has over 20 years experience with large-scale Enterprise systems software on mainframe, midrange, server and desktop systems. The periodical, Business Trends Quarterly, establishes a dynamic forum where business strategy experts and IT decision-makers analyze existing enterprise systems and challenges from an IT solutions standpoint.

Nair, R., & Smith, J. (2005). The Architecture of Virtual Machines. *Computer*, 38(5), 32-38. Retrieved November 19, 2008 from the Institute of Electrical and Electronics Engineers, Inc. http://ieeexplore.ieee.org/Xplore/login.jsp?url=/iel5/2/30853/01430629.pdf?arnumber=1430629)

**Abstract**: This article explores the architecture of virtual machines (VM). Virtualization has become an important tool in computer system design, and virtual machines are used in a number of sub-disciplines ranging from operating systems to programming languages to processor architectures. Because VM implementations lie at architected interfaces, a major consideration in the construction of a VM is the fidelity with which it implements these surfaces. Some of the important interfaces and implementation layers in a typical computer system are illustrated.

**Comment:** Very detailed article describing the hardware/software marriage that makes virtualization work. Article can be beneficial for hardware aspects of how VM's work and how to save hardware cost by using VM's. This article is used to support the history and the advantages and disadvantages (hardware/software) section of the document. This article is credible because it was published by a peer-reviewed publication (IEEE Computer Society). The authors are both professionals in their respective fields. Smith is a professor in the department of Electrical and Computer Engineering at the University of Wisconsin-Madison. Nair is a research staff member at the IBM T.J. Watson Research Center.

Ou, G. (2006). *Introduction to sever virtualization.* Retrieved December 1, 2008 from TechRepublic Web site: http://articles.techrepublic.com.com/5100-10878_11-6074941.html

**Abstract**: This article offers an introduction to server virtualization, from what virtualization is and why to use it, to when to use virtualization, to how to migrate physical servers to virtual servers, and more.

**Comment:** This is an article that describes the advantages and disadvantages of virtualization. The article also discusses licensing and migration – physical 2 virtual (P2V) issues, and what to watch for (all the eggs in one basket). This article is used to support the advantages and disadvantages section of the document. This article is credible because the author is Technical Director of TechRepublic. Former IT consultant specializing in Servers, Microsoft, Cisco, Switches, Routers, Firewalls, IDS, VPN, Wireless LAN, Security, and IT infrastructure and architecture. The online periodical,

TechRepublic, is part of the CBS Interactive brand, which is a premier online content network.

Posey, B. (2003). *The pros and cons of server virtualization*. Retrieved November 29, 2008 from TechRepublic Web site: http://articles.techrepublic.com.com/5100-10878_11-5057662.html

**Abstract**: Server virtualization combines many Web sites onto one server. This article looks at situations in which server virtualization is best used and discusses the benefits and potential problems.

**Comment**: Introduces some cons of virtualization – Scalability, Security and "bleed over" (when the contents of one virtual sever affect other virtual servers). This article is used to support the advantages and disadvantages (cons) section of the document. This article is credible because the author has written over 3,000 technical articles and written or contributed material to 27 books. He as also served as CIO for a chain of hospitals, as well as was in charge of IT security for Fort Knox. The online periodical, TechRepublic, is part of the CBS Interactive brand, which is a premier online content network.

Ramanathan, R.M., & Bruening, F. (2004). *Virtualization: Bringing Flexibility and New Capabilities to Computing Platforms.* Retrieved November 11, 2008 from Intel Web site: ftp://download.intel.com/technology/computing/archinnov/teraera/download/virtualization_0604.pdf

**Abstract**: The perceived complexities of computing systems are a deterrent to their pervasive adoption by users. The convergence of computing and communications can drive continuing growth, but this growth will not be sustainable unless we can find new

ways to transparently manage complexities and hide them from users. This paper provides a conceptual overview of a new concept – platform virtualization – that can be used to provide end-users with future computing systems that are as easy to use as consumer electronics equipment. Virtual platforms promise to make future computers more autonomous, reliable and trusted, making them an almost invisible tool in our day-to-day lives. Platform virtualization is a key enabler of new usage models designed to make these goals a reality. It is the road to the future of computing.

**Comment**: Detailed article on the benefits of virtualization. There is the possibly of bias because the paper is authored by Intel employees. This article is used to support the general advantages and disadvantages of virtualization segment of the document. When evaluating the credibility of a document, it is possible that this on the verge of not being credible because it is an Intel presentation, which has a high possibility of having a bias since Intel is involved with manufacturing and sales of virtualization components. However, it is included because it is writing for a professional audience, it is relevant to the topic, and the authors and company they represent are recognized in the field as authorities for the technology.

Reuben, J.S. (2007). *A Survey on Virtual Machine Security.* Helsinki University of Technology. Retrieved November 29, 2008 from http://www.tml.tkk.fi/Publications/C/25/papers/Reuben_final.pdf.

**Abstract**: Virtualization plays a major role in helping the organizations to reduce the operational cost, and still ensuring improved efficiency, better utilization and flexibility of existing hardware. "Virtualization is both an opportunity and a threat - says Patrick

Lin, Senior director of Product Management for VMware". This paper presents a literature study on various security issues in virtualization technologies. Our study focus mainly on some open security vulnerabilities that virtualization brings to the environment. We concentrate on security issues that are unique for virtual machines. The security threats presented here are common to all the virtualization technologies available in the market; they are not specific to a single virtualization technology. We provide an overview of various virtualization technologies available in the market at the first place together with some security benefits that comes together with virtualization. Finally we provide a detailed discussion of several security holes in the virtualized environment.

**Comment:** This paper covers the history of virtualization as well as details on specific security issues that can become an issue: guest-to-guest attack, denial of service, external modification of a VM and external modification of the hypervisor. This article is used to support the historical as well as advantages and disadvantages (security) section of the document. This paper is credible because it is a scholarly research paper written for the Helsinki University of Technology. It is written with good coverage of the topic and good quality of the writing.

Samoilenko, A. (2007*) Key Problems of Virtualization Deployment.* Byrds Research & Publishing. Retrieved December 1, 2008 from http://ixbtlabs.com/articles2/cm/virtualization-problems-page1.html

**Abstract:** Virtualization technologies radically change the standard approach to deploying an IT infrastructure. Despite all evident advantages of virtualization, its deployment raises a lot of serious problems. These problems can certainly be solved with

a competent approach. A key element of this approach is thorough planning of all virtualization deployment stages. This article discusses the planning stages as well as some of the areas to pay special attention to, such as disaster recovery strategies, OS licenses, and peculiarities of integration with the existing infrastructure.

**Comments:** This article is used to support the migration mediation portion of the document. The article is published on the iXBT Labs website. iXBT Labs is one of the top and most respected Moscow, Russia-based websites dedicated to reviewing different types of computer hardware since 1997. The document is published within the appropriate timeframe and there is good coverage of the topic.

Sun. (2008). The *Business Benefits of Virtualization and Consolidation with Sun and VMware.* Retrieved November 22, 2008 from http://www.sun.com/sunray/whitepapers/sun_vmware_benefit.pdf

**Abstract**: The combination of server technologies from Sun and virtualization technology from VMware can disrupt the status quo in IT environments and provide organizations with a new set of choices that can increase flexibility, reduce cost, and attack space, power, and cooling issues head-on.

**Comment:** Business benefits and disaster recovery information when using VM's. Good information on how to use VM's as a disaster recovery solution. Watch for bias – this is jointly produced by Sun and VMware. This article is used to support the advantages and disadvantages (business continuity and disaster recovery) section of the document. This document could be considered not credible because of bias that is introduced. This white paper describes how Sun and VMware team together and function on different Sun

hardware platforms. However, it is included because it provides good coverage of how virtualization technology works, the quality of the white paper is good, it is written for IT professionals or systems engineers, and it is current, falling within the time and date boundaries for the literature review.

VanDoorn, L. (2006). *Hardware Virtualization Trends*. Keynote presentation at the Second International Conference on Virtual Execution Environment, Ottawa, Canada. Retrieved November 30, 2008 from https://www.usenix.org/events/vee06/full_papers/vandoorn-keynote.pdf

**Abstract**: This presentation given at the Second International Conference on Virtual Execution Environment covers: virtualization 101, processor virtualization (Intel VT-x, VT-x2, AMD SVM), security enhancements, paravirtualization (software isolation approach), I/O Virtualization (AMD, Intel VT-d) and the hypervisor Landscape.

**Comments:** This article is used to support the advantages and disadvantages (TCO) of virtualization section of the document. This is a credible document because it is a keynote address for the "Second International Conference on Virtual Execution Environments" that was held in 2006 in Ottawa, Canada. The author is a senior manager at IBM's T.J. Watson Research center where he manages the secure systems and tools department.

Vanover, R. (2007). *Physical-to-virtual migration best practices*. Retrieved December 11, 2008 from the TechTarget website http://searchservervirtualization.techtarget.com/tip/0,289483,sid94_gci1283030,00.html

**Abstract:** This article provides some best practices to ensure a P2V (physical-to-virtual)

migration is successful and occurs without incident.

**Comments:** This article supports the migration mediation portion of the paper. This is a credible article because it is published on TechTarget's website. TechTarget provides enterprise IT professionals with the information they need to assist them with their careers - from developing strategy, to making cost-effective IT purchase decisions and managing their organizations' IT projects. The author is credible because he is an MCSA-certified system administrator for Belron US. His previous roles included software engineering roles with Siemens and Dematic, and working with complex supply chain execution systems. He has been working in the information technology field for over 10 years and virtualization technologies for over seven years and has been publishing articles online for over six years.

Vijayan, J. (2007). Virtualization Increases IT Security Pressures. *Computerworld*, 41(35), 14-16. Retrieved November 21, 2008 from http://www.computerworld.com/action/article.do?command=viewArticleBasic&articleId=301232

**Abstract**: The article reports that virtualization technology has caught the attention of information technology (IT) managers for its promise to let them better manage and utilize corporate IT resources in the U.S. According to Chad Lorenc, information security officer at a financial services company, IT security and compliance projects are far more complex undertakings on virtual machines than on servers that run a single operating system and application. Moreover, virtualization technologies allow companies to carve

out multiple virtual machines within a single physical resource such as a computer server or storage array.

**Comment:** This is a specific article on security concerns when running VMs in the environment. It provides good information on what precautions to take and what to watch for as far as software weaknesses. This article is used to support the advantages and disadvantages (security – con) section of the document. The article is credible because it is published on ComputerWorlds website. Computerworld has been the leading source of technology news and information for IT influencers worldwide. The author is a senior editor covering information security and data privacy issues for Computerworld. He's been with the publication since March 1994 and has covered a variety of topics including PC hardware, and enterprise technologies.

VMware (2006). *Virtualization Overview.* Retrieved November 15, 2008 from the VMware website: http://www.vmware.com/pdf/virtualization.pdf

**Abstract:** The article discusses basic virtualization concepts and the technology that VMware offers. The article covers the different virtualization approaches: hardware-level virtualization, operating system level virtualization, and high-level language virtual machines, and gives definitions of what the approaches are. The whitepaper discusses the different hardware platforms that VMware offers a solution for, and introduced the concept of para-virtualization.

**Comments:** This white paper is valuable because it gives incite on VMware's solutions as well as an overview of what virtualization consists of. This whitepaper is used to support the history of virtualization and the advantages and disadvantages section of the

document. The article could be considered not credible because it is a white paper for VMware, a company that makes virtualization software and therefore has a high possibility of having a bias. However, it is included because it covers the topic adequately, the article is written for an audience of IT professionals, VMware is an authority in the virtualization field when it comes to hardware virtualization on the x86 platform and the article is current.

# Review of the Literature

## Introduction

This study examines ways to reduce IT costs and increase IT efficiency by integrating platform-virtualization in the enterprise, which encompasses the virtualization of the physical hardware and the operating systems that reside on that hardware. Virtualization allows computer hardware to run multiple operating systems simultaneously, making it possible to time-share expensive hardware without requiring software modifications to legacy systems (Figueiredo et al, 2005).

The literature selected to form the basis of the review focuses on two main aspects of virtualization integration: reducing IT costs and increasing IT efficiency. Literature selected is mined for key words or terms using two methods: software based work frequency counter (Word Count Machine), and by manually searching, reviewing sources for the terms, and determining if the source is relevant to the research goals. Appendix A shows the frequency of the pre-selected key terms in each selected references.

The following review consolidates and summarizes information collected from these references in relation to the two key aspects of virtualization integration: reducing IT costs and increasing IT efficiency (The Strategic Counsel, 2007). Data collected are presented in an annotated framework format. The framework begins with a heading and general information about one of the three areas reviewed: a brief chronology of virtualization development, factors for consideration when migrating to a virtualization model in the enterprise, in relation to two pre-selected IT business functions, and the advantages and disadvantages of each factor.

**Brief Chronology of Virtualization Development**

The history of virtualization technologies spans over forty years. Although virtualization has been in development since the mid 1960s, it is just becoming popular in the enterprise today. IBM was the first to create virtual environments for various user tasks in mainframes (Samoilenko, 2007). The M44/44X project, worked on by IBM staff at the Watson Research Center, was designed to evaluate the emerging time-sharing system concepts. The architecture was based on virtual machines: the primary machine was an IBM 7044 (M44) and each virtual was an experimental image of the primary machine (44X) (Singh, 2006).

System VMs emerged during the 1960s and early 1970s. At that time, mainframe computer systems were very large, expensive, and usually shared among numerous users. With VM technology, different user groups could run different operating systems on shared hardware (Nair & Smith, 2005).

In 1970, IBM announced the IBM System/370 (also known as the S/370) mainframe series. These mainframes were significant because they supported the time-sharing operating system Control Program (CP) and Conversational Monitor System (CMS) referred as CP/CMS. A key feature of the CP/CMS design was the independence of each virtual machine (Creasy, 1981). The CP/CMS had direct ties with hypervisors, also known as virtual machine monitors (VMMs), which reached prominence in the early 1970s and achieved commercial success with the IBM 370 series (Figueiredo, 2005).

In 1981, IBM announced the System/370 Extended Architecture (XA). The new architecture that supported 31-bit addressing, XA I/O interfaces, improved contents management, well-defined interfaces to CMS system services, general-purpose multi-tasking, a

hierarchical file system, and a number of algorithmic improvements. In 1985, CMS was run successfully in a 200-megabyte XA virtual machine (Varian, 1997).

In the late 1990s, IBM released the Enterprise System Architecture (ESA). The VM/ESA release has two features - the ESA feature, and the 370 feature: a long awaited "single-VM" (Varian, 1997.) In 1991, the personal/370 card came from labs of IBM. Known as the P/370, it was a real System/370 on a card. Varian (1997) described it this way: "… it had about the same capacity as a 4381-P13 and ran as a co-processor in a PS/2. Really slick OS/2 programs were used to emulate channels and control units to make PC devices look like mainframe devices to VM n the P/370. What made the P/370 so exciting was that it ran real S/370 operating systems, such as the VM/ESA 370, without modification" (p. 65).

As noted by Conoops (2007), the IT industry has more recently revisited an old idea, which IBM has been using successfully within its mainframe environments for over 40 years. In 1998 VMware delivered the benefits of virtualization to industry-standard x86-based platforms, which now form the majority of desktop, laptop and server shipments (VMware, 2006). The first x86 virtualization product, "VMware Virtual Platform", which was based on earlier research by VMware's founders while at Stanford University, was released in February 1999. A wealth of knowledge has been built up from the days of mainframe data centers which are applicable to the new virtualization paradigm (Conoops, 2007). Virtualization broadly describes the separation of a resource or request for a service from the underlying physical delivery of that service. Virtualization techniques can be applied to other IT infrastructure layers such as networks, storage, laptop or server hardware, operating systems and applications. This blend of virtualization technologies, known as the virtual infrastructure, provides a layer of abstraction

between computing, storage and networking hardware, and the applications running on it (Figure 1) (VMware, 2006).

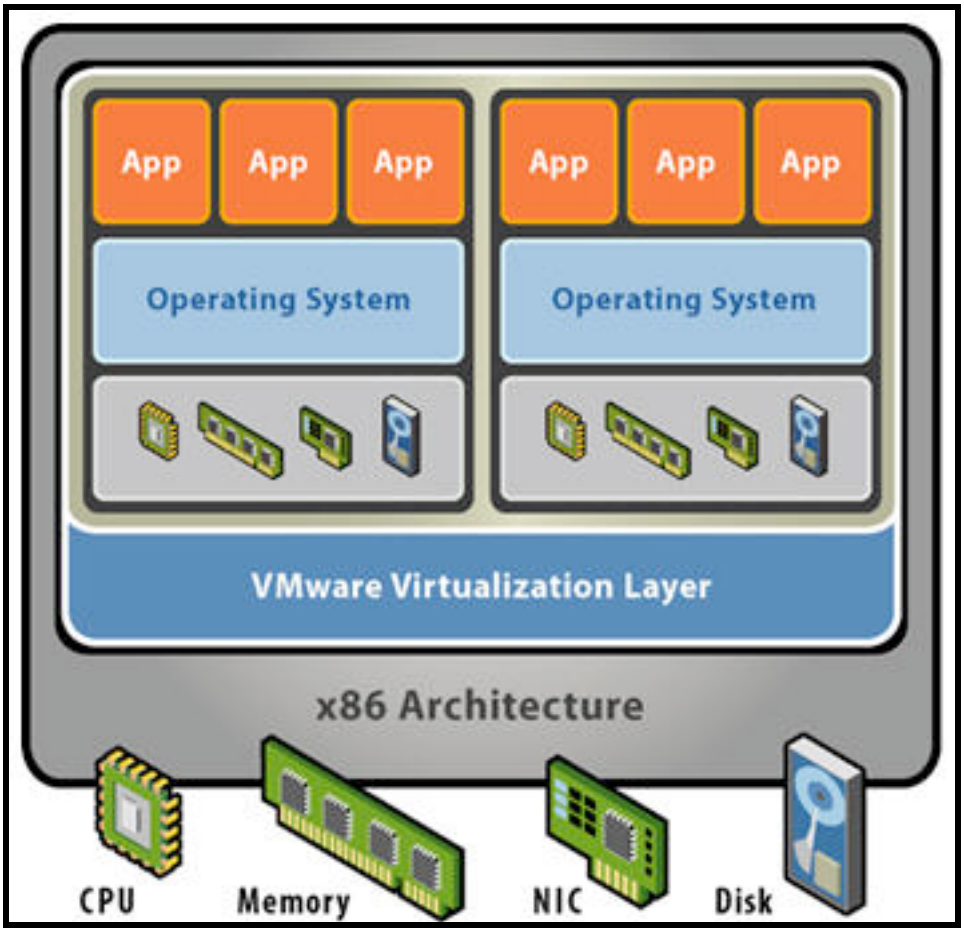


Figure 1: Virtualization Layers

Duntemann (2005) describes virtualization as "special software creates a CPU mechanism called a virtual machine (VM), in which Windows can run under Windows, in a window—as can Linux, OS/2 Warp, Solaris, or almost any other operating system written for x86 hardware. The virtualization software is called a virtual machine manager (VMM) or hypervisor." (p. 2).

At this point, it appears that server and desktop virtualization offer many benefits, both financially and operationally. However, like any complex technology implemented in IT, it has

its share of advantages and disadvantages to be aware of (Goldworm, 2008). The next section of this literature review identifies some of the factors for consideration when implementing a virtual system into the enterprise as well as their advantages and disadvantages. Focus is on two selected business functions identified by the Strategic Counsel (2007): reducing IT costs and increasing IT efficiency. The review identifies the advantages and disadvantages for the selected business functions when migrating from an existing environment to a virtual one.

## Business Function #1: Reducing IT Costs

Information Technology (IT) organizations are increasingly implementing virtualization as a solution to dramatically lower data center costs and increase competitive advantage (Miller & Sarno, 2006). Server consolidation, test and development agility, licensing consolidation, standardization, as well as power and physical space consolidation are some of the main ways to reduce IT costs in the enterprise. Each is examined in detail below.

### *Server consolidation and IT costs*

Server consolidation through virtualization has played an important role in the reduction of IT costs by reducing the amount of hardware required to perform necessary computing tasks (Miller & Sarno, 2006). Single server utilization rates, as reported by VMware, are between 5% and 15%. The virtualization of servers onto one platform can increase that utilization to potentially 60% to 80%. Eliminating 'server sprawl' via deployment of systems as virtual machines (VMs) that can run safely and move transparently across shared hardware, results in increased server utilization rates (VMware, 2006). The main advantage of this consolidation is cost savings to the enterprise. Server consolidation and improved server utilization are one of the traditional drivers as well. Enterprises can combine the workload from multiple underutilized

physical machines into a single physical system, which dramatically reduces overall hardware spending, as it requires far fewer physical systems for the same application workload (Mann, 2007). EDS, a global technology services provider, provides an example of cost savings through server consolidation for the U.S. Navy. EDS has helped the military in consolidating 1,200 x86 servers down to 200, each hosting multiple VMware ESX virtual machines. The project goal is to consolidate more than 2,700 servers down to 300 – a 9:1 ratio. The normal technology refresh budget of $1.5 million has decreased to $500,000 (Babcock, 2008). Server consolidation has been the main application for virtualization, with some organizations seeing consolidation rates of up to 30 to one (Conoops, 2007). Server consolidation thus remains a key driver for virtualization related to reduction of IT costs. Ou (2006) gives this example: "If you have a data center full of aging servers running on sub-GHz servers, these are the perfect candidates for P2V migration. You could literally take a room with 128 sub-GHz legacy servers and put them into eight 1U dual-socket quad-core servers with dual-Gigabit Ethernet and two independent iSCSI storage arrays all connected via a Gigabit Ethernet switch. The annual hardware maintenance costs alone on the old server hardware would be enough to pay for all of the new hardware" (p. 3).

There are disadvantages to server consolidation. The most cited disadvantage is described by Christer (2007) as having "many eggs in the same basket (hardware failure can take down many servers)" (p. 19). The single-point-of-failure issue—failure of a single consolidated component will have a greater potential impact on IT costs than failure of one of several redundant components (Kline & Whyms, 2007). Cost reduction is feasible by replacing ten servers with one high-end server; however, by doing this, redundancy is reduced. If a host goes down due to a hardware malfunction, all guests are unavailable to the organization. The option of

using clustering technology with a second or a third server is available; however, implementing this will raise hardware costs as well as add another layer of complexity. It would be difficult to save on hardware costs by replacing ten average servers with two or three high-end servers (Pietroforte, 2008). Having the appropriate level of redundancy and a complete disaster recovery plan can mitigate this problem (Chen & Xin, 2005).

### *Test and development agility and IT costs*

Part of the advantage of business agility in relation to IT costs derives from test and development agility. Staff can develop and test new capabilities side-by-side on multiple operating systems, and benefit from faster build/test/rebuild cycles (especially across multiple operating systems) (Schwab, 2006). Virtualization reduces mundane deployment processes for production implementation to minutes instead of days or weeks, reduces procurement time, and results in fewer hardware compatibility issues (Mann, 2007). Deploying any new application, requires quality assurance (QA) testing to ensure it runs well in its installed environment and other applications continue to work properly (Marshall, 2007). Most virtual machine software today provides snapshot and rollback capabilities (Chao, 2006). These capabilities allow an administrator to record a snapshot, or image, of the file system and installed applications to disk. Having the ability to rapidly provision test and development servers by reusing pre-configured VMs, increases the rage of development and can help standardize the development environment (VMware, 2006). Using this process saves time, and thus is less costly, than installing an operating system and the application(s) separately, and will effectively bring the hardware and software to an original state. Using virtualization to create a simulation lab, in which large, complex-computing environments can be replicated on a small scale, is useful for testing computing environment changes, such as firewall rules, to see how the environment reacts (Kline

& Whyms, 2007). Having the ability to take snapshots and restore as needed, saves time, which in turn saves money. Evaluators can now create a new VM, install a piece of software, and test it without risking a Windows reinstall. When the test is done, the entire VM state (including the software being evaluated) is simply archived (generally to a server) or discarded (Duntemann, 2005). Because of the versatility, virtual machines can be used to create arbitrary test scenarios, and can lead to some very imaginative, effective quality assurance (Singh, 2006).

Test and development in a virtual environment does have some disadvantages in relation to IT costs. One of the biggest disadvantages is the possibility of "virtual sprawl." Virtual sprawl is the proliferation of virtual machines without adequate IT control. The central problem behind sprawl is that virtual machines are so easily generated, or copied, that IT staff have potential problems tracking how many there are, and when and where they are deployed in the environment (Brodkin, 2008). If virtual sprawl occurs, time, and therefore money, is wasted by IT staff trying to track down these rogue VMs. Brodkin (2008) states "if you don't have good VM management and good governance in place you're actually going to cost your company money. Virtual server sprawl can wipe out any savings." (p. 1).

***Licensing and IT costs***

Software licensing can be a challenge when implementing a virtual environment in the enterprise. License models are traditionally hardware oriented (number of installations, CPU capacity, core processors, and so on). One advantage to virtualization is that in some situations where licensing is not an issue. For example, when migrating from a single server model to a virtual model, there is no need to purchase new server licenses or application licenses (Ou, 2006). In this type of case, the only additional licensing that is needed is the virtualization

software license. Ou (2006) states, “You don't even need to worry about license acquisition costs because the licenses are already paid for” (p. 4).

But with virtualization the hardware relationship is lost. According to Weinberg (2008), there is a direct conflict between software licenses and emerging technology, meaning all issues pertaining to software licensing, which are already perplexing for most customers, will become even more complex with virtualization.

There are other disadvantages with licensing in a virtual environment related to IT costs. Mann (2007) points out that “cost accounting and licensing become much harder in a virtual environment. Enterprises need to measure highly dynamic resource usage, not just acquisition costs. Some tools exist that can help, but they are rare and incomplete. One solution for licensing costs is to look at open source opportunities (e.g. Xen or OpenVz on Linux, etc.) to obviate licensing issues, but this is unlikely to resolve all the pertinent issues” (p. 4).

It is recommended that administrators examine the license conditions of all manufacturers affected by their virtualization program, and if needed renegotiate terms, purchase or update the licenses, or find a different product to fill the need that is more cost effective. It is also recommended that a software license management tool should be implemented to provide decision makers with licensing information throughout the virtual environment. Licensing mistakes can lead to costs that significantly exceed the savings in hardware expenses (Weinberg, 2008). Vanover (2007) also recommends to “make sure the original system that was migrated to the virtual environment is not repurposed, but retired. After migration, you do not want to find out that the original system that was migrated to the virtual environment still exists as a physical system for another purpose” (p. 2).

***Standardization and IT costs***

There are many IT cost advantages to standardization of hardware and software. A standardized hardware platform reduces support costs and increases the share of IT resources that can be devoted to accomplishing goals that support competitive advantage (Chao, 2006). If the virtual environment is primarily used for test or development agility, a snapshot of the operating system and applications can be restored on standard hardware. When IT organizations standardize on an operating system and a specific set of patches, they can create a "golden master" virtual disk image, and deploy virtual servers simply by making new copies of the disk image files (Sun, 2008). Peters (2008) points out that "by using three or four standard hardware combinations your, IT staff has a chance to get comfortable and knowledgeable with these systems, allowing them to diagnose and fix problems more quickly and easily. Another advantage to standardizing hardware is that some hardware components are incompatible with other pieces or hardware or software. The fewer different pieces of hardware you support, the less frequently you'll encounter this problem" (p. 2). Table 2 lists some of the benefits of standardization:

| **Benefits of Standardization** |
| --- |
| • Provides support for current and future applications and workloads.<br>• Offers business continuity support for higher availability systems from rapid and automatic system restarts and or fail-over to secondary sites.<br>• Frees organizations from vendor-imposed upgrades for both hardware and software.<br>• Provides support for legacy systems on modern, state-of-the-art servers. |

| Benefits of Standardization |
| --- |
| • Allows resources within servers and among pools of servers to be balanced and changed dynamically in response to changes in workload or business priorities.<br>• Helps increase availability with security and fault isolation.<br>• Facilitates the use of pooled, centralized storage systems without the need to assign a unique and secure logical unit to each server or application.<br>• Provides instant provisioning by coping 'golden master' installations of operating systems and patches.<br>• Supports business continuity through copying and migrating virtual disk images.<br>• Supports maintenance with zero downtime through the ability to migrate running virtual machines to alternate platforms when a server must be powered off for maintenance. |

Table 2: Benefits of standardization

There are a few disadvantages related to IT costs to standardizing with one vendor. First is the potential for loss of bargaining power, which may result in not getting the best price available on the hardware or software. One suggestion around this is to have a different vendor available to regain some of the lost bargaining power. If the primary vendor knows that the same product is available from a secondary supplier, the primary vendor may be inclined to offer the best pricing structure. A second disadvantage is the possibility of experiencing delays in receiving replacement equipment. Using one manufacturer can slow down operations if equipment has yet to be released or is on backorder (Norton, 2002).

### *Power and physical space consolidation and IT costs*

Companies are finding ways to be more environmentally responsible. One way of accomplishing this is to utilize virtualization in the environment. Radding (2007) states that

"Garner, a consulting company that provides fact-based consulting services that helps clients use and manage IT to enable business performance, is also focusing on energy costs. 'Through 2009, energy costs will emerge as the second highest operating cost in 70 percent of worldwide data center facilities,' reports Michael Bell, research vice president at Gartner. Servers, Bell continues, 'represent the biggest consumers of power and cooling, amounting to 40 percent of the overall power consumption. At that point, energy costs will be exceeded only by labor as the major data center operating costs'" (p. 1).

Datacenter optimization is also an advantage in virtualization. Several existing servers consolidated as VMs on a single server saves both space and power and reduces heat and cable clutter (Duntemann, 2005). With the workloads of multiple legacy servers consolidated onto a single server, IT organizations can economize on space, power, and cooling (Sun, 2008). By reducing the number of servers, a company can reduce the number of dedicated rooms that require specialized power, conditioning, and physical security. Server consolidation benefits result from a reduction in the overall number of systems and related recurring costs (power, cooling, rack space, etc.) (VMware, 2006).

This researcher did not identify any disadvantages in the selected literature for power and physical space consolidation. One possible disadvantage is the cost of replacement of equipment. If the existing hardware cannot support a virtual environment, hardware replacement can potentially cost more than keeping, and upgrading, single servers in the datacenter. The cost of power and room space may be less expensive than purchasing modern equipment. Feuless (2007) provides and example what he states "vendors may also try to protect their revenue stream by influencing the consolidation solution itself. In one instance vendor A indicated the client could consolidate on a 2/1 ratio using their hardware; vendor B indicated the client could consolidate

on an 8/1 ratios using their hardware; and vendor C (an independent consulting firm predicted a 25/1 ratios with either vendor A or B's equipment" (p. 2).

**Business Function #2: Increasing IT Efficiency**

***Centralized security and IT efficiency***

Virtualization offers many security advantages in relation to IT efficiency. One of the key reasons to employ virtualization is to isolate applications from each other. As stated by Chao (2006), virtual machines allow you to isolate each application (or group of applications) in its own "sandbox" environment. Nair-Smith (2005) points out that "if security on one guest system is compromised or if one guest operating system suffers a failure, the software running on other guest systems is not affected" (p. 5). Table 3 lists the common security benefits of virtualization.

| Security Benefits of Virtualization |
| --- |
| • It makes available a centralized and secured computing environment.<br>• Having a clean "golden image" that can be restored over the top of a malware-infected system to instantly restore a clean, secure environment.<br>• The ability to share systems without sharing sensitive data by each booting up their own virtual environment.<br>• It offers fast and secure restore of environments for shared systems, such as compromised servers, user systems, or shared terminals.<br>• It provides secure, isolated testing and debugging for potentially harmful applications, malware, new applications, and new security scenarios. |

Table 3: Security benefits of virtualization

A whitepaper published by Sun (2008) points out that "virtualization at the hardware level encapsulates each guest operating system in its own virtual machine, containing faults to a

single environment. This helps increase reliability by limiting the propagation of faults, and allowing them to be handled by software, rather than hardware mechanisms. Likewise, because each virtual machine isolates its guest operating system and applications, any security flaw affecting one environment does not affect another" (p. 8).

Centralized security on virtual machines also has disadvantages in relation to IT efficiency. The primary problem of centralized security in a virtual environment can be divided into two parts: The security of a virtual machine (guest) and the security of a virtualization platform (host) (Samoilenko, 2007). Both host and guest systems will still are susceptible to vulnerabilities, and system security best practices should still be followed. A good position to take is to treat the virtual environment with the strongest security controls needed to protect the most sensitive data in the guest operating systems, regardless of the hardware architecture or virtualization technology used. It is critical that the guest and host operating systems are maintained with the latest security patches (Kirch, 2007).

***Centralized administration (isolation, reporting, server management, log reviews, etc.) and IT efficiency***

Migrating from a physical to a virtual environment has many administrative advantages. Centralized administration gives the administrator better control over the environment. Environmental changes such as testing installations of new software can be completed in a test environment without affecting the production environment. Administrators can snapshot a system, install some software, or make some configuration changes that they suspect may destabilize the system. If the software installs or changes succeed, the administrator can commit the updates to the production system(s). If the updates damage or destroy the system, the

administrator can either troubleshoot the cause of the failure, or decide to cancel the installation altogether (Chao, 2006). By unifying a diverse server virtualization environment management across platforms, solutions and technologies should prove to be a key future area of development for vendors and users alike, and will play a key role in increasing server virtualization deployment satisfaction levels (The Strategic Counsel, 2007).

A disadvantage in relation to IT efficiency is that there are no formalized standards in place for virtual server management; however, there are standards for server management in general that can be followed (Pietroforte, 2008.) Without standardization, there are specific gaps identified in tools to facilitate patch management, x86-based server aggregation, backup and restore management, and workload balancing optimized for virtual servers (Ferguson, 2006). Another disadvantage is the next generation of security attacks may be directed at virtualization software. Some security researchers warn that virtualization makes corporate systems far more vulnerable to hackers (Vijayan, 2007).

***Legacy systems support and IT efficiency***

Some organizations need to continue to run legacy applications on legacy operating systems but are faced with expired service contracts on hardware that cannot be replaced due to the lack of drivers for new hardware (Sun, 2008). Legacy systems fall into one of two categories: hardware or software. Often a legacy system is operating on out of date hardware that is hard to maintain, improve, or expand because there is a lack of support from the vendor, general lack of understanding of the system by the support staff, or replacement hardware is no longer available. Integration with newer systems within the organization may also be difficult because new software may use completely different technologies. A legacy application might simply not run

on newer hardware and/or operating systems. Even if it does, if may under-utilize the server. This may be difficult without virtualization since applications are usually not written to co-exist within a single execution environment (Singh, 2006).

Administrators managing legacy software, such as Windows 3.51, NT, 95/98, older versions of Linux or proprietary software can also run into the same issues. Virtualization can be used to re-host legacy applications while providing a standard platform for all future application deployments (Sun, 2008). The need to run legacy applications is served well by virtual machines (Singh, 2006). A whitepaper published by Sun (2008) states "Moving to a virtualized environment and standardizing on a server platform gives IT organizations additional benefits that can help them to better manage their resources, including: Providing support for legacy systems on modern, state-of-the-art servers" (p. 13).

The disadvantage of virtualizing a legacy system or any virtualized server is known as 'bleed over'. Bleed over occurs when the contents of one virtual server affect other virtual servers and may be a concern when creating a virtual environment (Posey, 2003).

***Reduction of downtime and IT efficiency***

Consolidation will allow consistent system administration with a goal geared toward a reduction in downtime (Chen & Xin, 2005). Downtime is an issue that IT organizations have to manage, now more than ever (Conoops, 2007). Even organizations that have well coordinated suites of applications have to consider bringing them down occasionally to carry out routine maintenance on the application or the server(s). Many of them have adopted a "zero downtime" approach, and are unwilling to allow system downtime during business hours (Sun, 2008). With business now conducted on more of a global scale, maintenance windows have shrunk considerably (Conoops,

2007). Virtualization reduces downtime for physical system maintenance, whether planned or unplanned (Mann, 2007). By straddling multiple physical servers, critical servers or services never need to be down because of a single hardware failure or for general maintenance (Ou, 2006).

The Strategic Counsel (2007) reported that some of the top business cases listed by organizations favoring virtualization show a strong link between IT drivers and actual uses for server virtualization. These business cases are continuity/disaster recovery and managing hardware migrations/upgrades (e.g. to eliminate downtime). When assessing the financial impact of downtime, which can occur in either business case, you need to consider factors such as potential lost revenue, reductions in worker productivity, and damaged market reputation. Downtime can even reduce shareholder confidence, which can create unnecessary and unplanned costs (Iron Mountain, n.d).

With virtualization in operation, virtual servers or virtual applications can be moved from one physical (host) server, which is requiring maintenance, to other host servers for the duration of the maintenance activity. With all workloads moved off a server, it then can be taken offline for maintenance, upgraded, or even replaced without affecting the availability of the applications that were running on it. Once the repair, upgrade, or replacement is complete, virtual machines can be moved back to the original server (Sun, 2008).

This researcher did not identify any disadvantages in the selected literature for using virtualization to help reduce downtime in an organization. However, there is a potential disadvantage of virtualization in the event of a critical hardware failure. If the virtualization server (host) suffers a critical failure and goes down, so do all the virtual servers hosted by the

now failed virtualization server (Kline & Whyms, 2008). Therefore it is important to plan and budget for redundancy within the system so the possibility of downtime is reduced.

### *Staff Education and IT efficiency*

With the implementation of new technology into the enterprise, it is important to have the staff that is supporting the technology trained. It is critical to ensure the technical staff understands the principles of virtualization (Conoops, 2007). Additionally, there are new skills that are needed, specific to the virtual environments themselves - VM tuning, virtual network configuration, virtual storage configuration (Conoops, 2007). With the introduction of a virtual infrastructure, new roles within the IT organization will emerge. With the new rolls, questions must be asked regarding which rights should be delegated to existing specialists (system administrators, network administrators, tech support specialists, security specialists) (Samoilenko, 2007).

The disadvantage of education is training availability. Training is not always available and training specialists from scratch is time-consuming and complex. The lack of specialists of a required level is one of the three main reasons why companies refuse to start using virtualization (Samoilenko, 2007). Mann (2007) summarizes the main concern with "enterprises should not underestimate the potential for human issues to affect their virtualization plans adversely. Virtualization requires a new set of skills and methodologies within both IT and the end-user community - including new and creative thinking, not just new training and skills. Departments and business owners may baulk at sharing resources. Enterprises should be prepared to deal with these human issues early and often in their virtualization projects" (p. 4).

## Conclusion

Virtualization of x86 hardware is steadily gaining popularity, and can be applied in operator environments, hosting provider environments, corporate networks. It can also be used by individual users. Virtualization is becoming more and more feasible for widespread use, and with increased use, dependence on virtualization technology is also increasing (Vaarala, 2006).

Brown and Crosby (2007) state "virtualization represents a basic change in the architecture of both systems software and the data center. It offers some important opportunities for cost savings and efficiency in computing infrastructure, and for centralized administration and management of that infrastructure for both servers and clients." (p. 41).

Deciding whether or not to deploy virtualization – or deciding where to deploy it and where to stay with legacy systems – is a complex and case-specific process. No two enterprises will get the same benefits from virtualization (Mann, 2007). Businesses are deploying virtualization for a number of larger benefits. Server consolidation, test and development agility, licensing consolidation, standardization, as well as power and physical space consolidation are some of the main ways to reduce IT costs in the enterprise. The Strategic Counsel (2008) reports efficiency benefits of server virtualization as improved server and system utilization rates, improved server reliability and uptime, and improved business continuity and disaster recovery.

One of the most important findings from this literature review is to take time to plan the new virtualized environment. Implementing a virtual environment for the sake of virtualization may impact the business. Virtualization that sacrifices too much performance for the sake of device-independence will most likely not be accepted (Plessl, 2004). The key to create a good virtualization environment is to study the environment carefully that is to be virtualized, the needs and goals of the organization, and to take into consideration all the possible issues that put

the virtual environment at risk (Reuben, 2008). Since specific server virtualization benefits enjoy strong alignment with IT-specific drivers for virtualization deployment, expectations of benefit, and actual server virtualization use cases, metrics should be developed to help support business case development based on these known quantities (The Strategic Counsel, 2008).

Each virtualization deployment is different, and it is rare that any single use case will achieve all of the benefits. The key is in gaining a complete understanding of the environment, the need, and the goals, and matching the right virtualization solution to the business (Mann, 2007). Virtualization technologies change the standard approach to deploying an IT infrastructure. Despite the evident advantages of virtualization, its deployment raises potential problems. These problems can be resolved with a competent approach. A key element of this approach is thorough planning of all virtualization deployment stages (Samoilenko, 2008).

An additional concern when migrating servers into a virtual environment is security. Virtualization is a powerful solution to reduce the operational costs in today's computing but if done wrong it can become a risk to the environment. Security problems that have already solved in the physical environment have cropped up again in the virtual one (Brodkin, 2008). As an example, it is critical that the guest and host operating systems maintain the latest security patches to avoid exposing the environment to unnecessary risk of not just the individual target but the entire virtual environment (Kirch, 2007). Keeping up with security measures while implementing the company's security model, and continuous monitoring for new developments that emerge in the field, will help withstand possible attacks (Reuben, 2008).

There are some significant challenges which need to be dealt with and resolved before a business can deploy and manage a virtual environment (Schwab, 2006). Mann (2007) identifies three main challenges or issues as: technology issues, human issues, and cost issues. Figure 4

shows examples of the challenges that should be addressed when deciding whether or not to implement virtualization.

| Challenges of Virtualization | |
|---|---|
| ***Technology issues*** | Are the applications suitable, or supported, for a virtual environment?<br><br>Are the right management technologies for virtual environments in place or available?<br><br>Is the network infrastructure robust enough to support the bandwidth requirements?<br><br>Is there enough storage capacity in place for the potential expansion that virtualization will bring? |
| ***Human factors*** | Is the IT staff prepared for virtualization?<br><br>What level of training will be required to make them ready?<br><br>Will virtualization be able to be roll-out to the organization without significant disruption to the business?<br><br>Do you have significant departmental and political divides that will affect a decision to virtualize? |
| ***Cost issues*** | Are you prepared for the cost of the initial deployment of virtualization technology?<br><br>How much will you need to spend on new hardware, new software, new staff, training, development, and additional licenses?<br><br>Do you know what your cost benefit expectations are?<br><br>Have you prepared a comprehensive return on investment analysis? |

Table 4: Challenges of virtualization

The Strategic Counsel (2008) states “server virtualization is enjoying tremendous growth because it has clear, known benefits. The challenge is driving increased server virtualization deployment satisfaction levels by quantifying benefits in business-related terms and metrics, defining and following deployment best-practices, and developing and implementing management solutions for multiple, heterogeneous server virtualization environments.” (p. 32).

Implementing virtualization in a company can reduce IT cost through one or several of the following avenues: server consolidation, test and development agility, licensing consolidation, standardization, and/or power and physical space consolidation. It can also increase IT efficiency through: centralized administration and/or security, support of legacy systems, reduction of server downtime, and/or providing the staff training on a new technology. The system administrator or other IT professional should take the time to review the organization's overall strategic direction, and then apply virtualization based on those requirements.

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# Appendix A: Frequency of Key Terms in Selected Literature

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| **Chao** | Cost (s) | 15 | 15 | Pg. 1-4 | Y |
| | History | 0 | 0 | | |
| | Efficiency | 1 | 1 | Pg. 2 | N |
| | Virtualization | 5 | 6 | Pg. 1,3 | Y |
| | Virtual | 61 | 61 | Pg. 1-4 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 3 | 3 | Pg. 1,4 | Y |
| | Cons | 3 | 3 | Pg. 1,4 | Y |
| **Conoops** | Cost (s) | 8 | 8 | Pg. 2-4,7 | Y |
| | History | 1 | 1 | Pg. 5 | N |
| | Efficiency | 2 | 2 | Pg. 2,3 | Y |
| | Virtualization | 53 | 31 | Pg. 3-7 | Y |
| | Virtual | 26 | 24 | Pg. 4-7 | Y |
| | Return on Investment (ROI) | 2 | 2 | Pg. 2,3 | Y |
| | Total Cost of Ownership (TCO) | 1 | 1 | Pg. 3 | Y |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| **Duntemann** | Cost (s) | 0 | 0 | | |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 14 | 16 | Pg. 1-3 | Y |
| | Virtual | 21 | 17 | Pg. 1-3 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |
| **Figueiredo** | Cost (s) | 4 | 4 | Pg 2,3 | N |
| | History | 1 | 1 | Pg. 3 | N |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 31 | 30 | Pg. 1-4 | Y |
| | Virtual | 25 | 23 | Pg. 1-4 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 1 | 1 | Pg. 2 | Y |
| | Pros | 0 | 0 | | |
| | Cons | 2 | 0 | | |
| **Hamm** | Cost (s) | 0 | 0 | | |
| | History | 0 | 0 | | |

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| | Efficiency | 0 | 0 | | |
| | Virtualization | 26 | 26 | Pg. 2-4 | Y |
| | Virtual | 6 | 5 | Pg. 2-4 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |
| **Kennedy** | Cost (s) | 0 | 0 | | |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 18 | 21 | Pg. 1-3 | Y |
| | Virtual | 17 | 15 | Pg. 1-3 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 1 | 0 | | |
| | Cons | 0 | 0 | | |
| **Kirch** | Cost (s) | 3 | 3 | Pg. 3,26 | N |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 47 | 26 | Pg. 7,9-16,20,23,25,26 | Y |

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| | Virtual | 121 | 104 | Pg. 7-13,15-17,19-26 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |
| **Kline** & Whyms | Cost (s) | 3 | 2 | Pg. 16 | Y |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 1 | 23 | Pg. 3,6,8-11,13-16 | Y |
| | Virtual | 9 | 7 | Pg. 10,13-16 | Y |
| | Return on Investment (ROI) | 1 | 1 | Pg. 14 | N |
| | Total Cost of Ownership (TCO) | 3 | 3 | Pg. 16,43 | Y |
| | Pros | 2 | 2 | Pg. 13 | Y |
| | Cons | 2 | 2 | Pg. 14 | Y |
| **Mann** | Cost (s) | 15 | 15 | Pg. 2-6 | Y |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 77 | 65 | Pg. 1-6 | Y |
| | Virtual | 18 | 17 | Pg. 1-6 | Y |
| | Return on | 1 | 1 | Pg. 6 | N |

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| | Investment (ROI) | | | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 2 | 1 | Pg. 1 | Y |
| | Cons | 2 | 1 | Pg. 1 | Y |
| **Nair-Smith** | Cost (s) | 0 | 0 | | |
| | History | 0 | 0 | | |
| | Efficiency | 2 | 2 | Pg. 6 | N |
| | Virtualization | 14 | 14 | Pg. 1,2,5,6 | Y |
| | Virtual | 38 | 38 | Pg. 1-6 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 4 | 0 | | |
| | Cons | 4 | 0 | | |
| **Ou** | Cost (s) | 11 | 11 | Pg. 1,3,4 | Y |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 33 | 33 | Pg. 1-4 | Y |
| | Virtual | 27 | 27 | Pg. 1-4 | Y |
| | Return on Investment (ROI) | 1 | 1 | Pg. 1 | Y |
| | | | | | |
| | Total Cost of | 0 | 0 | | |

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| | Ownership (TCO) | | | | |
| | Pros | 1 | 1 | Pg. 4 | N |
| | Cons | 1 | 1 | Pg. 4 | N |
| **Posey** | Cost (s) | 5 | 3 | Pg. 1-2 | Y |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 16 | 16 | Pg. 1-2 | Y |
| | Virtual | 2 | 2 | Pg. 3 | Y |
| | Return on Investment (ROI) | 1 | 0 | | |
| | Total Cost of Ownership (TCO) | 1 | 0 | | |
| | Pros | 2 | 1 | Pg. 1 | Y |
| | Cons | 2 | 1 | Pg. 1 | Y |
| **Ramanathan** | Cost (s) | 6 | 6 | Pg. 3 | Y |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 33 | 31 | Pg. 2-8 | Y |
| | Virtual | 16 | 14 | Pg. 2,4-6,8 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 3 | 3 | Pg. 3-4 | Y |
| | Pros | 0 | 0 | | |

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| | Cons | 0 | 0 | | |
| **Reuben** | Cost (s) | 2 | 2 | Pg 1,5 | Y |
| | History | 0 | 0 | | |
| | Efficiency | 2 | 2 | Pg. 1-2 | Y |
| | Virtualization | 62 | 60 | Pg. 1-5 | Y |
| | Virtual | 88 | 84 | Pg. 1-5 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 4 | 0 | | |
| | Cons | 4 | 0 | | |
| **Samoilenko** | Cost (s) | 5 | 1 | Pg. 2 | N |
| | History | 1 | 1 | Pg. 1 | Y |
| | Efficiency | 7 | 5 | Pg. 3,4,6 | Y |
| | Virtualization | 105 | 79 | Pg. 1-6 | Y |
| | Virtual | 80 | 73 | Pg. 1-6 | Y |
| | Return on Investment (ROI) | 1 | 1 | Pg. 3 | Y |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |
| **The** | Cost (s) | 31 | 31 | Pg. 2,4,7,19,23,24,26-28,31,33 | Y |

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| **Strategic Counsel** | History | 0 | 0 | | |
| | Efficiency | 10 | 10 | Pg. 4,5,19,20,23,24,31,33 | Y |
| | Virtualization | 272 | 272 | Pg. 1,2,4,5,7-9,13-21,23-31,33,34 | Y |
| | Virtual | 6 | 0 | | |
| | Return on Investment (ROI) | 35 | 35 | Pg. 2,4,14,26-29,31,33 | Y |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |
| **Sun** | Cost (s) | 5 | 5 | Pg. 1,3,11 | Y |
| | History | 1 | 1 | Pg. 3 | N |
| | Efficiency | 1 | 1 | Pg. 3,5 | N |
| | Virtualization | 29 | 29 | Pg. 1-16 | Y |
| | Virtual | 59 | 64 | Pg. 1-16 | Y |
| | Return on Investment (ROI) | 2 | 2 | Pg. 3,14 | N |
| | Total Cost of Ownership (TCO) | 1 | 1 | Pg. 14 | N |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |
| **Vandoorn** | Cost (s) | 1 | 3 | Pg. 4,17 | Y |
| | History | 0 | 0 | | |

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| | Efficiency | 0 | 0 | | |
| | Virtualization | 10 | 79 | Pg. 1-44 | Y |
| | Virtual | 17 | 25 | Pg. 4,6,9,11,13,18-20,22,26,31-33,36,40,41,43 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 2 | Pg. 4 | Y |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |
| **Vanover** | Cost (s) | 1 | 1 | Pg. 4 | Y |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |
| | Virtualization | 16 | 21 | Pg. 1-4 | Y |
| | Virtual | 49 | 39 | Pg. 1-4 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |
| **Vijayan** | Cost (s) | 0 | 0 | | |
| | History | 0 | 0 | | |
| | Efficiency | 0 | 0 | | |

| Article Author | Term(s) | Word Count Machine 2.5.1 Word Frequency | Manual Word Frequency | Page(s) | Relevant to Report (Y/N) |
|---|---|---|---|---|---|
| | Virtualization | 7 | 8 | Pg. 1-2 | Y |
| | Virtual | 38 | 34 | Pg. 1-2 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 0 | 0 | | |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |
| **VMware Whitepaper** | Cost (s) | 11 | 12 | Pg. 3,4,6-8 | Y |
| | History | 0 | 0 | | |
| | Efficiency | 2 | 5 | Pg. 4,6,8 | Y |
| | Virtualization | 72 | 58 | Pg. 1-5, 7-10 | Y |
| | Virtual | 53 | 63 | Pg. 1-10 | Y |
| | Return on Investment (ROI) | 0 | 0 | | |
| | Total Cost of Ownership (TCO) | 1 | 1 | Pg. 7 | Y |
| | Pros | 0 | 0 | | |
| | Cons | 0 | 0 | | |